3.2.8. UV VARIABILITY IN THE ALASKAN ARCTIC

Objectives

With support from the Arctic Research Initiative (ARI) in 1997 and 1998, a network of three UV meters was installed in Alaska, at BRW and at the NWS offices at Nome and St. Paul Island. The objective of this network is to provide information on the geographical distribution and temporal trends of UV radiation at climatically diverse sites in the Arctic.

Methods and Results

This network was maintained with support from ARI in FY 2000 and 2001, and included annual calibrations at the manufacturer. In addition, LI-COR sensors and data acquisition systems were installed at Nome and St. Paul Island to measure both downwelling and upwelling photosynthetically active radiation (PAR). The data from the upward and downward sensors can be used to provide information on changes in albedo to aid in the assessment of UV variability. Further information about the instruments, site descriptions, or requests for data access can be obtained from CMDL's website (http://www.cmdl.noaa.gov/star/index.html).

Table 3.11 provides an overview of the monitoring periods for 1998-2001 at the three sites. The table also provides information on the number of days with good and bad data, calibration dates at Biospherical Instruments Inc. (BSI), and comments. With the exception of Barrow and Nome for 2000, there has been less than a 10% loss in data during the monitoring period each year. In 2000, the losses of data at BRW and Nome were due to a PC malfunction and not to instrument failure. Unfortunately, since data are downloaded onto a PC, there is no way to retrieve lost data.

Of all three UV meters, the BRW instrument has exhibited the best stability, with a ±4% drift or less on four of the channels (305, 320, 340, and 380 nm). The stability of any one channel is evaluated by comparison of calibration factors, which are provided after the instruments undergo an absolute calibration each winter by the manufacturer. Unfortunately, there is a significant drift in the 313-nm channel for all three instruments, where the calibration factors have changed by as much as 40% from one year to the next. Therefore, until the problem is resolved and data are corrected, any interpretation about dose rates at 313 nm is not possible. As noted in Table 3.11, a channel was changed in the UV instrument at St. Paul for 1999 and 2000. The replacement of any channel makes an evaluation of stability problematic. In addition, when the St. Paul instrument was returned to the manufacturer in December 1999 for calibration, the diffuser was found to have leaked. This would affect all channels within the instrument's housing and therefore invalidate a comparison of calibration factors from the previous year. Although Nome had only Therefore, there is no 340-nm channel for either Nome or

TABLE 3.11. Site Summary of UV Monitoring at Barrow, Nome, and St. Paul, for 1998-2001

	1998	1999	2000	2001
		Barrow		
Start of monitoring	May 15	Feb. 3	Feb. 8	March 29
End of Monitoring	Oct. 27	Nov. 1	Oct. 16	Oct. 31
Good days	158	244	213	
Bad days (% loss)	4 (2.5%)	5 (2.1%)	24 (10.1%)	
Calibrations at BSI	April 30, 1998; Dec. 17, 1998	Dec. 9, 1999	Dec. 12, 2000	
Comments	Diffuser replaced in March 1998 and recalibrated April 1998		PC malfunction	
		Nome		
Start of monitoring	June 11	Feb. 24	Feb. 9	Feb. 9
End of monitoring	Oct. 24	Oct. 28	Nov. 6	Nov. 9
Good days	134	226	237	
Bad days (% loss)	5 (3.6%)	10 (4.2%)	30 (11.2%)	
Calibrations at BSI	April 28, 1998	Feb. 16, 1999; Dec. 1999	Dec. 12, 2000	
Comments	320-nm channel replaced in Dec. 1998		22 days lost because of PC malfunction	
		St. Paul		
Start of monitoring	June 6	March 1	March 7	Feb. 27
End of monitoring	Oct. 25	Oct. 14	Nov. 3	Nov. 7
Good days	135	211	231	
Bad days (% loss)	7 (5%)	16 (7%)	7 (2.9%)	
Calibrations at BSI	April 30, 1998	Feb. 16, 1999	Jan. 25, 2000; Dec. 12, 2000	
Comments	320-nm channel replaced in Dec. 1998	380-nm channel bad from March 1 to June 10, 1999	305-nm channel replaced prior to Dec. 2000 calibration	

St. Paul. Monthly averages were computed if there were 18 days or more per month with good data.

An annual variability in UV levels is clearly evident for all three sites, with maximum values for all wavelengths in May or June (Figure 3.30). Nome has the highest UV levels at 305 and 320 nm for all three years compared with BRW and St. Paul. Barrow is at the highest latitude of the three sites, and therefore would receive much less solar radiation over the course of the year, even when the Sun is above the horizon for 24 hours per day. St. Paul is usually under the influence of low-level stratus clouds, which would block more incoming UV radiation. Nome has many days that are spectacularly clear. The anomalously low UV levels at 305

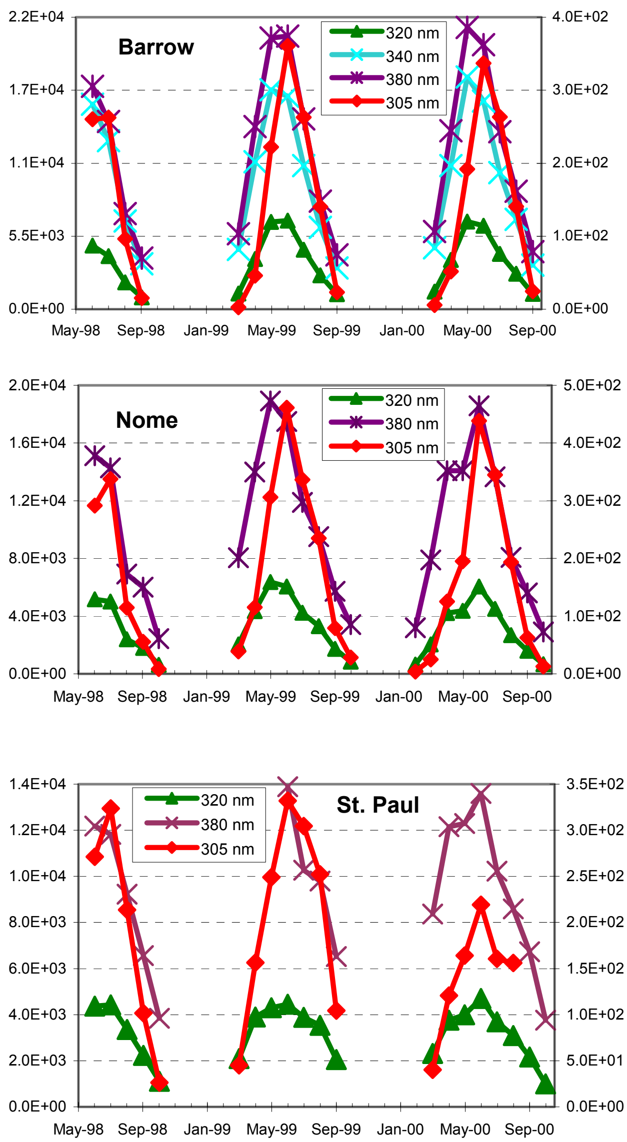

Fig. 3.30. Monthly average of daily total energy (J m^{-2} nm^{-1}) for 1998-2000 for Barrow, Nome, and St. Paul. The 305-nm channel is plotted on the right scale.

nm at St. Paul in the year 2000 are most likely due to a reduced sensitivity in that channel over the monitoring period, which necessitated its replacement in December (see Table 3.11).

In 2000, two LI-COR PAR sensors were installed at both St. Paul and Nome. A PAR sensor measures in the 400-700 nm solar spectrum. At both sites, one sensor faces upward (to measure downwelling or incident PAR) and the other sensor faces downward (to measure upwelling or reflected PAR). Table 3.12 summarizes the monitoring periods for the LI-COR sensors at St. Paul and Nome. Of the 338 days of data for St. Paul for 2000-2001, 212 were found to be good. The remaining 126 days had a downwelling PAR offset of 5 W m^{-2} or greater, which will be corrected later using a linear regression technique. This will enable all the data to be evaluated for 2000. At Nome, data were obtained for 232 days during 2000-2001; 225 of these were considered good days. The remaining 7 bad days were due to missing data. To investigate whether the LI-COR downwelling PAR is equivalent to the measurements obtained by the BSI PAR at Nome and St. Paul, a linear regression was applied with the 1-min solar noon values obtained from each instrument. At St. Paul, both the LI-COR sensor and BSI PAR compare very well, with an average difference between the two instruments of only about 4% (comparing only the 2000 data). However, at Nome, the LI-COR PAR measurements are 65% below those obtained by the BSI PAR during 2000, and the sensitivity of the LI-COR sensor appeared to be decreasing in 2001. Fortunately, the LI-COR downwelling PAR at Nome and St. Paul track the BSI PAR (r^2 = 0.99 at both sites), so the Nome LI-COR downwelling data were easily corrected using the equation obtained from the linear regression analysis.

TABLE 3.12. Summary of LI-COR PAR Sensors at Nome and St. Paul

	2000	2001
	St. Paul	
Start of monitoring	March 29	March 19
End of monitoring	Nov. 20	Nov. 15
Good days	108	104
Bad days (% loss)	126 (54%)	0 (0%)
Comments	From Nov. 20, 2000, to March 19, 2001, the downwelling PAR was turned off and sensor returned for repair	
	Nome	
Start of monitoring	April 11	April 22
End of monitoring	Aug. 29	Dec. 31
Good days	147	78
Bad days (% loss)	7 (5%)	0 (0%)
Comments	From Aug. 29, 2000, to March 29, 2001, the upwelling PAR was turned off and sensor returned for repair	Although the upwelling PAR sensor was re-deployed on March 29, 2001, it was incorrectly installed until April 22

When a ratio of the reflected flux density to the incident flux density is taken, one can obtain the albedo of the surface. In the Arctic the surface albedo can vary from less than 0.05 to more than 0.9. Figure 3.31 provides a preliminary analysis of albedo for Nome and St. Paul for 2000 and up to the last day of processing in 2001 (July 8). The albedos were calculated with data from sunrise to sunset (or for solar zenith angles between 0° and 85°). Days showing an offset were not included in the analysis for this report. In 2000 the range of albedos at Nome was 0.03 to 0.52; at St. Paul, the range was 0.03 to 0.95. St. Paul shows much lower albedos for the March-April period in 2001. At first, this was thought to be due to an instrument malfunction. However, upon examination of the meteorological observations for St. Paul, the albedos in Figure 3.31 are representative of both snow depth and snowfall amounts that were reported in both years. St. Paul had snow depths of more than 0.6 m (2 ft) throughout March and into mid-April in 2000. Only on May 1 did the snow depths decrease from 10.2 cm (4 in) to a trace, thus the dramatic decrease seen in the albedo for St. Paul in early May 2000. In contrast, 2001 was a very dry year for St. Paul, with little to no snow accumulation from January through April. This is reflected in the low albedo values, with the exception of a peak on March 27, which is most likely due to the fact that St. Paul received 1.5 cm (0.6 in) of snow that day. The next few days had trace amounts of snowfall, and albedo was seen to decrease. Even a small snowfall of 1.5 cm was enough for the albedo to increase threefold. At Nome the instrument did not operate correctly when it was installed in the early part of 2000. If it had, it is quite likely that measured albedos would have been as high as those seen for St. Paul because snow depths were greater than 0.6 m (2 ft) prior to April 4, but then plummeted to 12.7 cm (5 in) in less than 2 weeks, with little to no additional measurable precipitation after April 22,

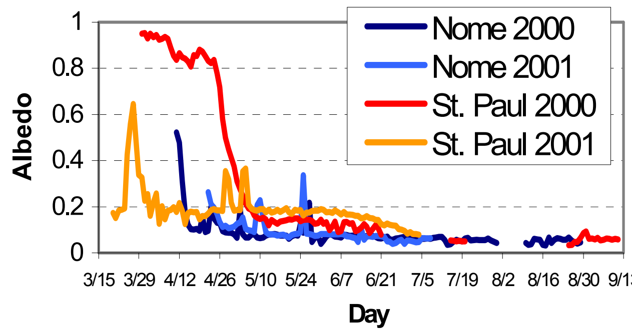

Fig. 3.31. Daily average albedo for Nome and St. Paul for 2000 and 2001, calculated with data from sunrise to sunset.

when the albedo reached its minimum levels. The large amount of missing data for the beginning of 2001 at Nome is due to bad weather that made it impossible for the site operator to install the repaired sensor, and when the sensor was installed in late March, it was erroneously inverted until April 22. Had the sensor been installed sooner and the inversion discovered earlier, more than likely the measured albedos would have been as high as St. Paul in 2000 because Nome received substantial snowfall that spring. The two peaks, on May 9 and again on May 25, are the result of two snowfall events, with more than 5.1 cm (2 in) measured each time.

Figure 3.32 shows the annual variability of daily total column ozone (Dobson units) obtained from the Total Ozone Mapping Spectrometer (TOMS) for the three sites for 1998–2000. Not shown on this plot is the ozone obtained from the Dobson spectrophotometer, which is

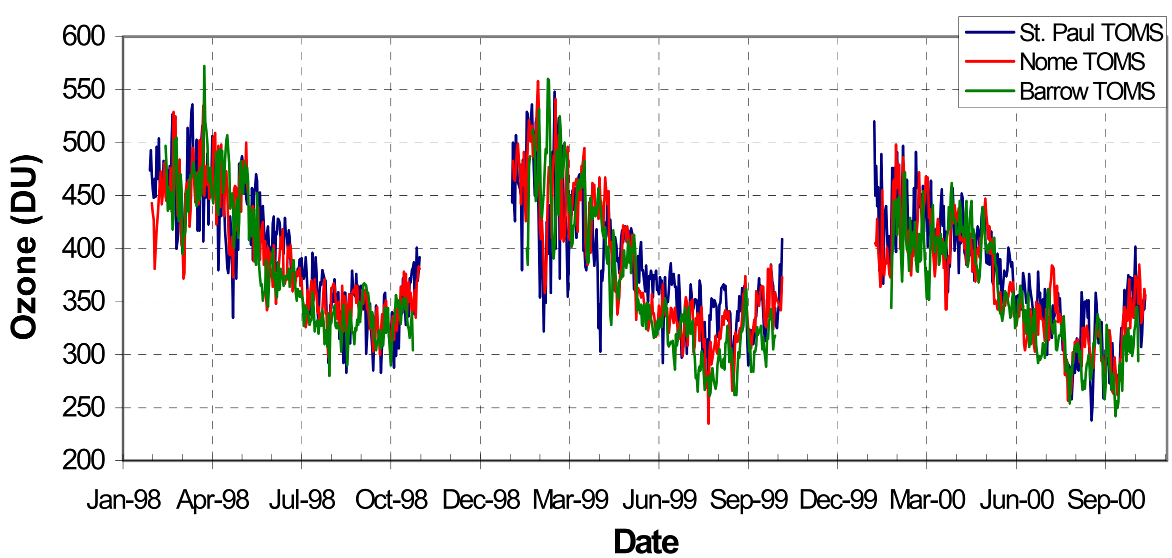

Fig. 3.32. Daily total column ozone from the Earth Probe Total Ozone Mapping Spectrometer (TOMS) for St. Paul, Nome, and Barrow, 1998–2000.

located at BRW. A linear regression analysis between the Barrow TOMS and Dobson ozone indicates that for all 3 years both data sets are highly correlated, with $r^2 = 0.98$. However, TOMS consistently overestimates total column ozone by an average of 3.4% (averaged over all 3 years) and as high as 10%. As can be seen in Figure 3.32, for all three sites, the maximum levels of ozone occur in February or March and then decrease over the course of the summer, with minimum levels of ozone occurring in August, September, or October. Note the lower maximum ozone levels at all three sites in February and March 2000 as compared with 1998 and 1999. Low levels of ozone were also found during the SAGE III (Stratospheric Aerosol and Gas Experiment) Ozone Loss and Validation Experiment (SOLVE) in early March 2000, when scientists from the United States, Canada, Russia, and Japan measured ozone losses as high as 55% across much of Scandinavia and north central Siberia.

In conclusion, these three sites can be used to evaluate long-term trends in UV and ozone, and the data can be used by researchers doing impact-related analyses as well as by the satellite community to improve algorithms used to estimate UV. This is important because of expected ozone losses over the next 20 years or more due to a cooling stratosphere in the Arctic region, with potential impacts on human health and on the marine and terrestrial ecosystems.